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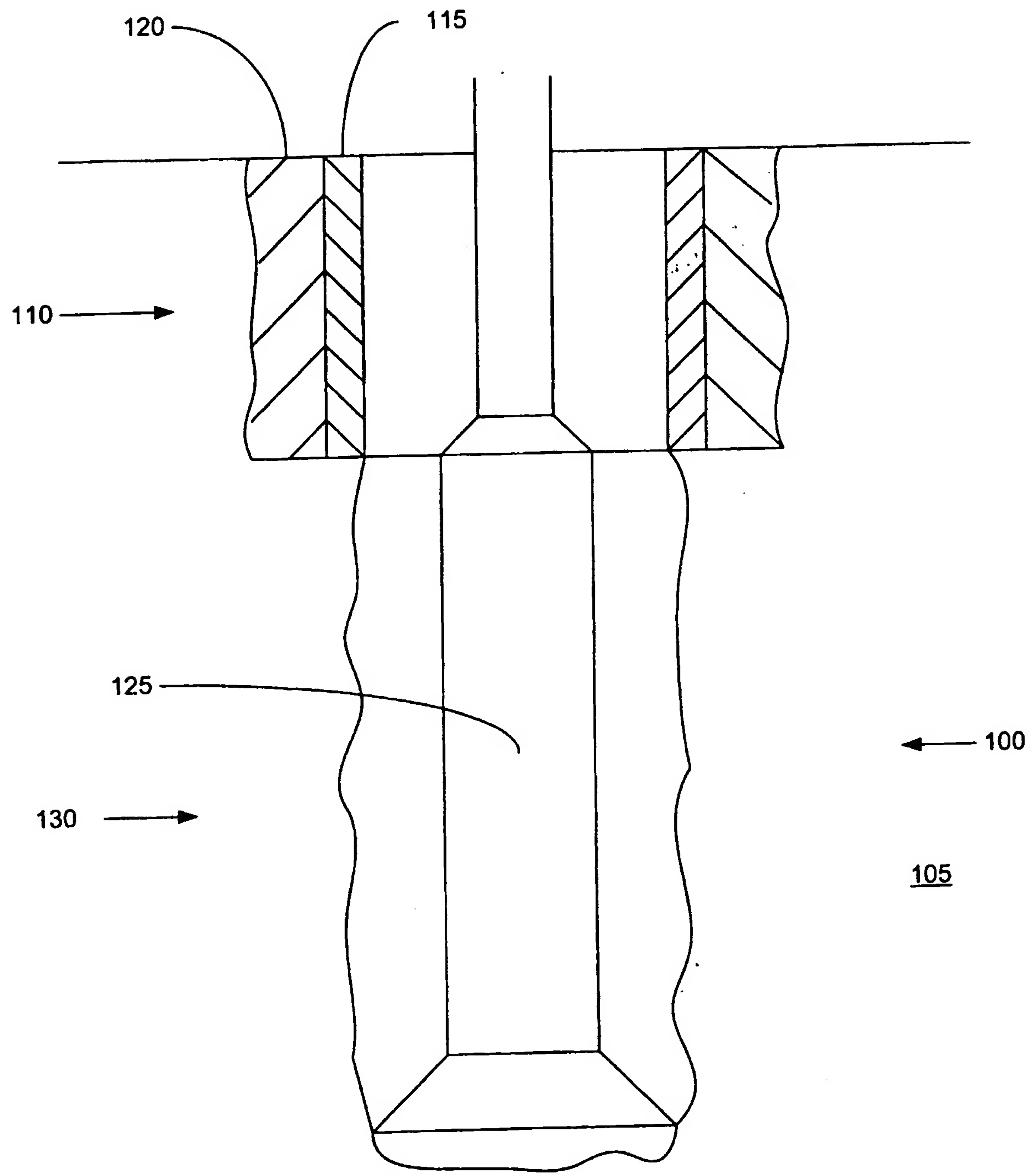

FIGURE 1

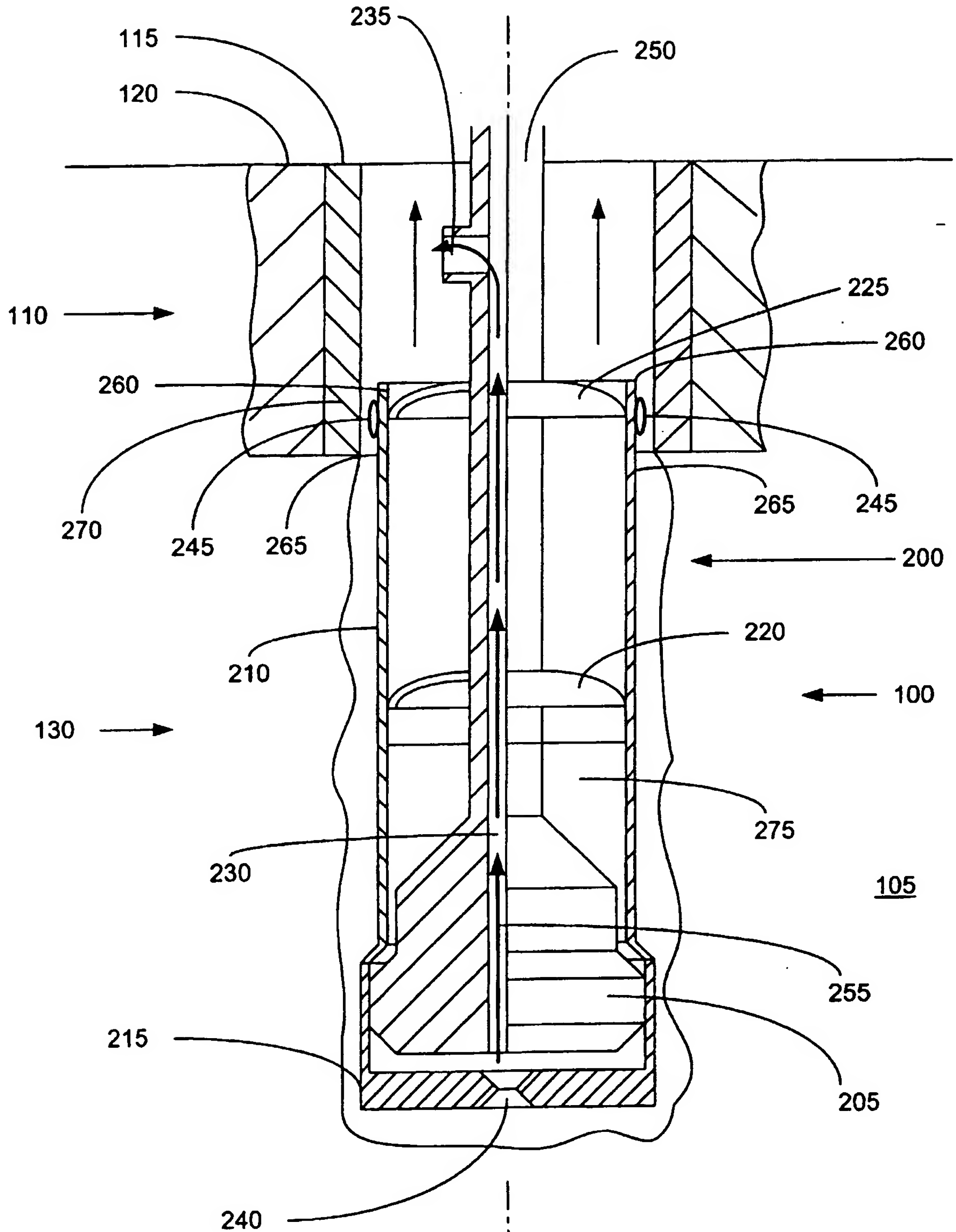

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FIGURE 2

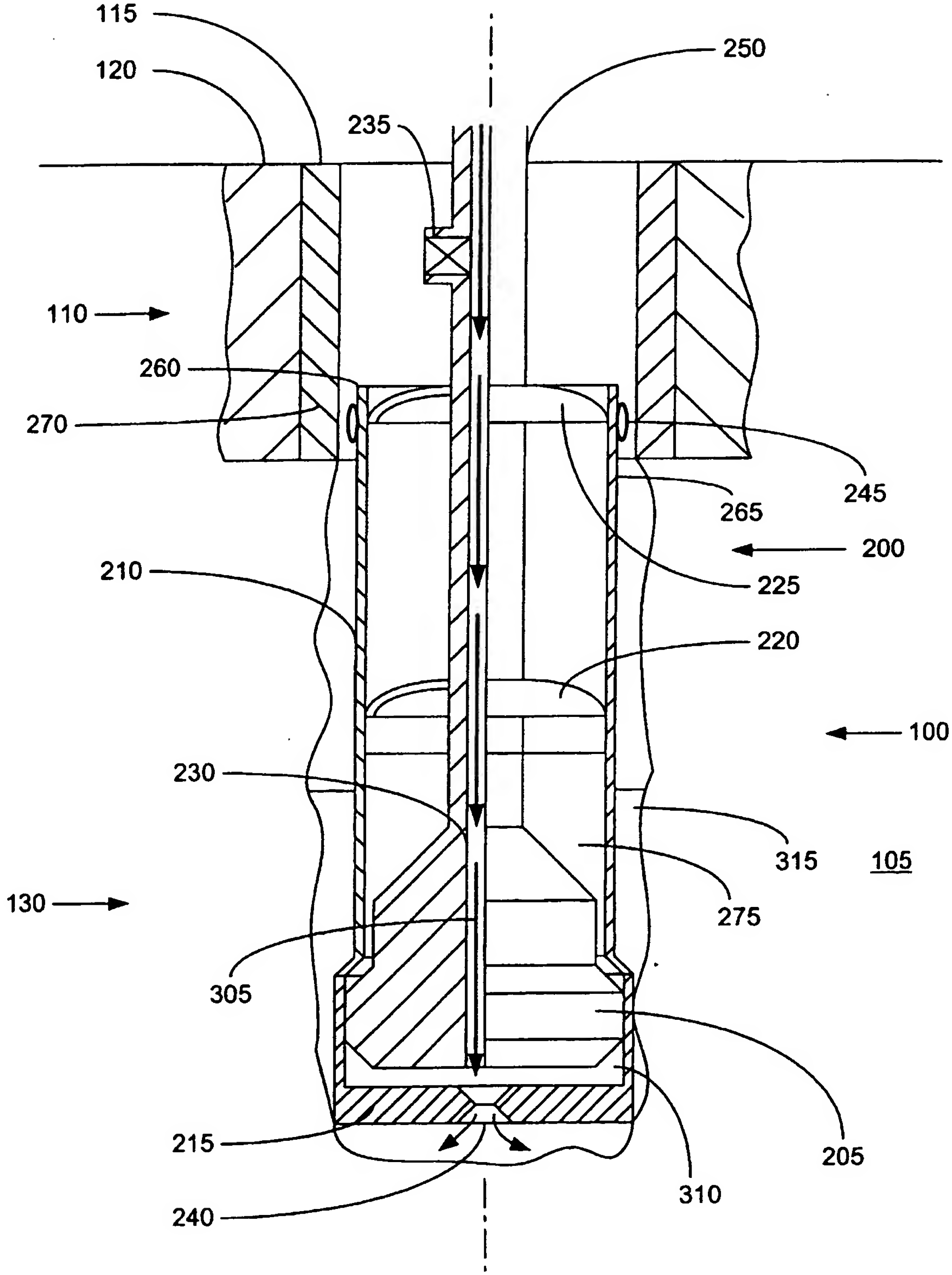
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FIGURE 3

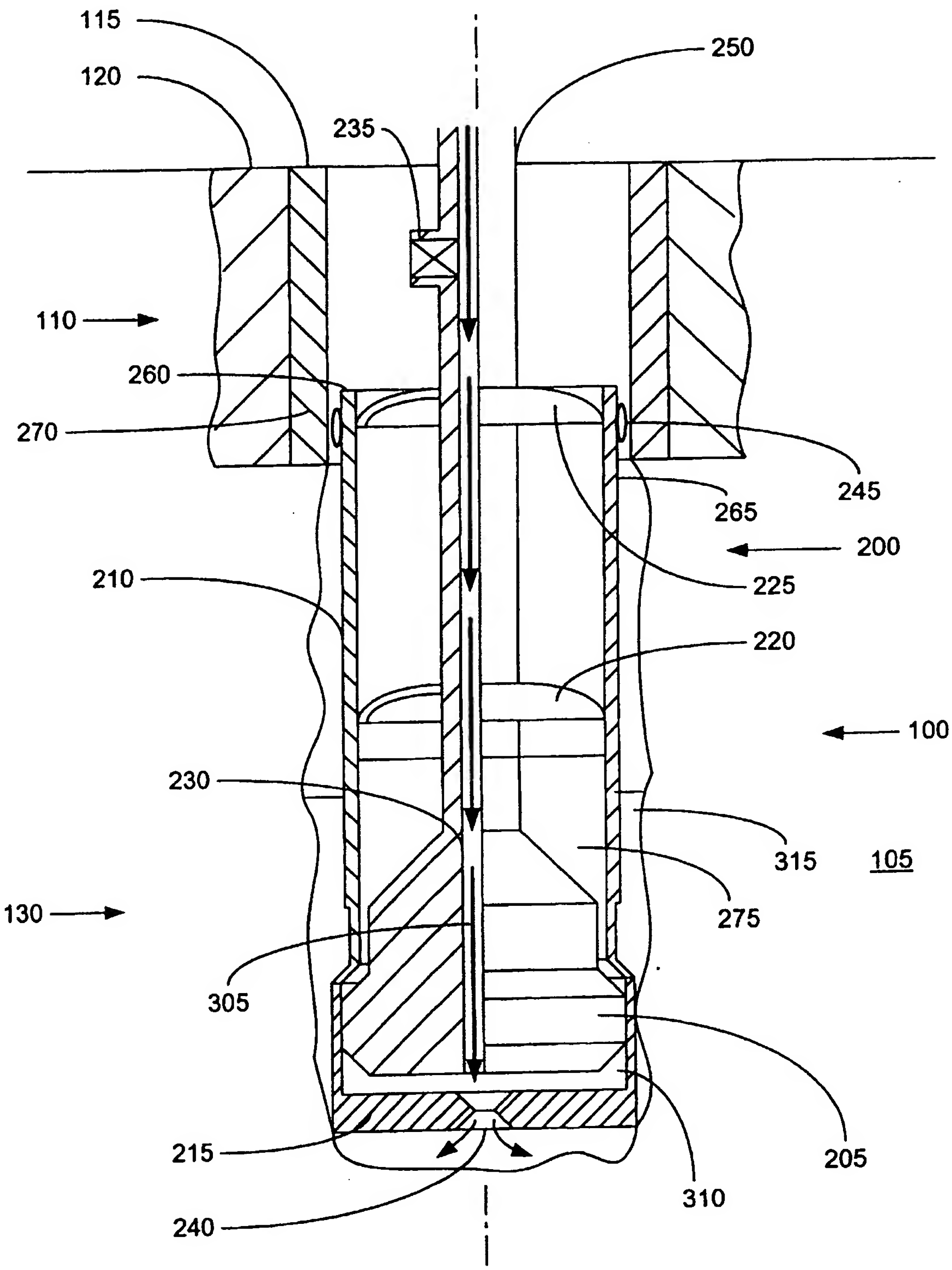

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FIGURE 3a

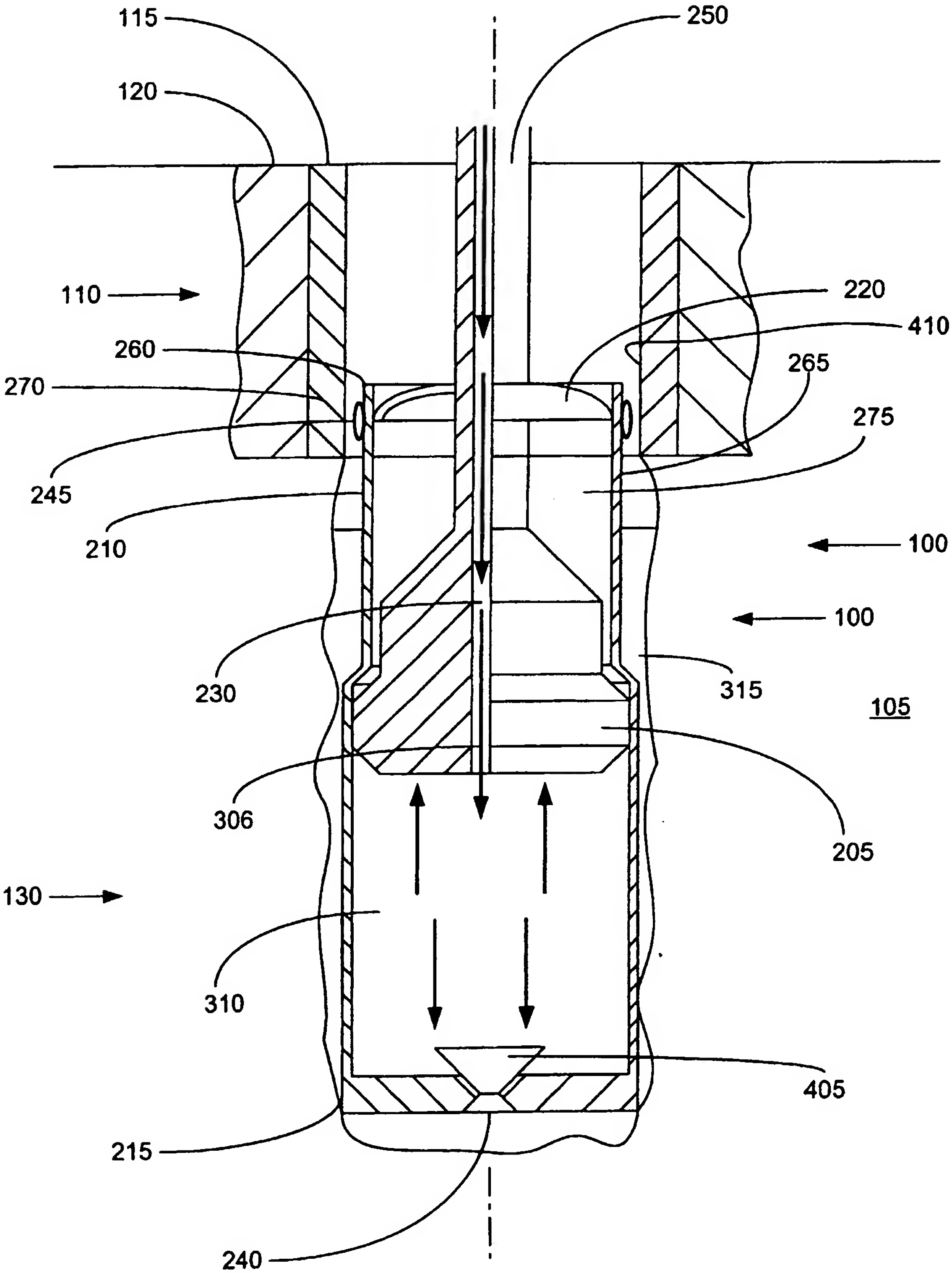
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FIGURE 4

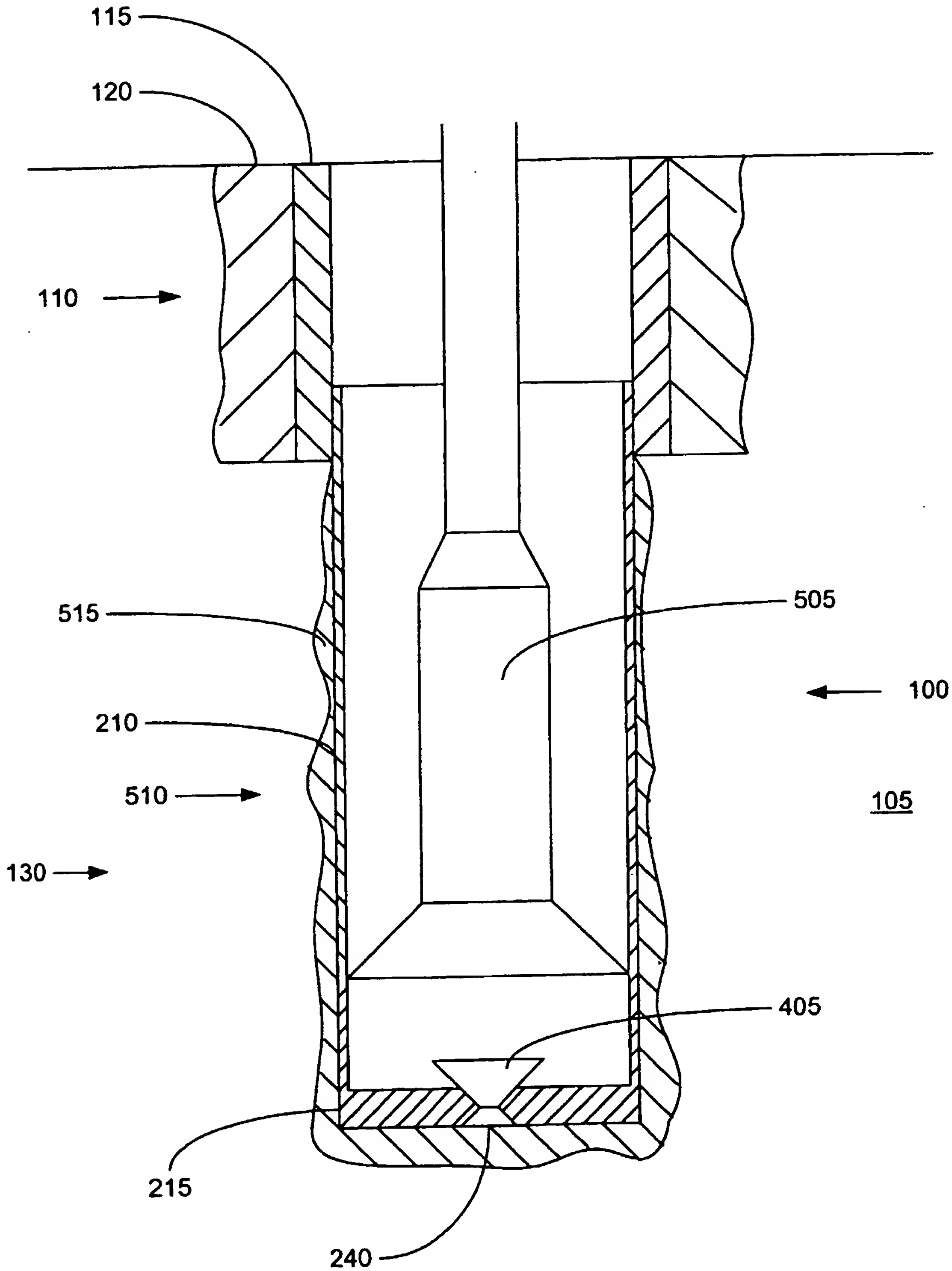

FIGURE 5

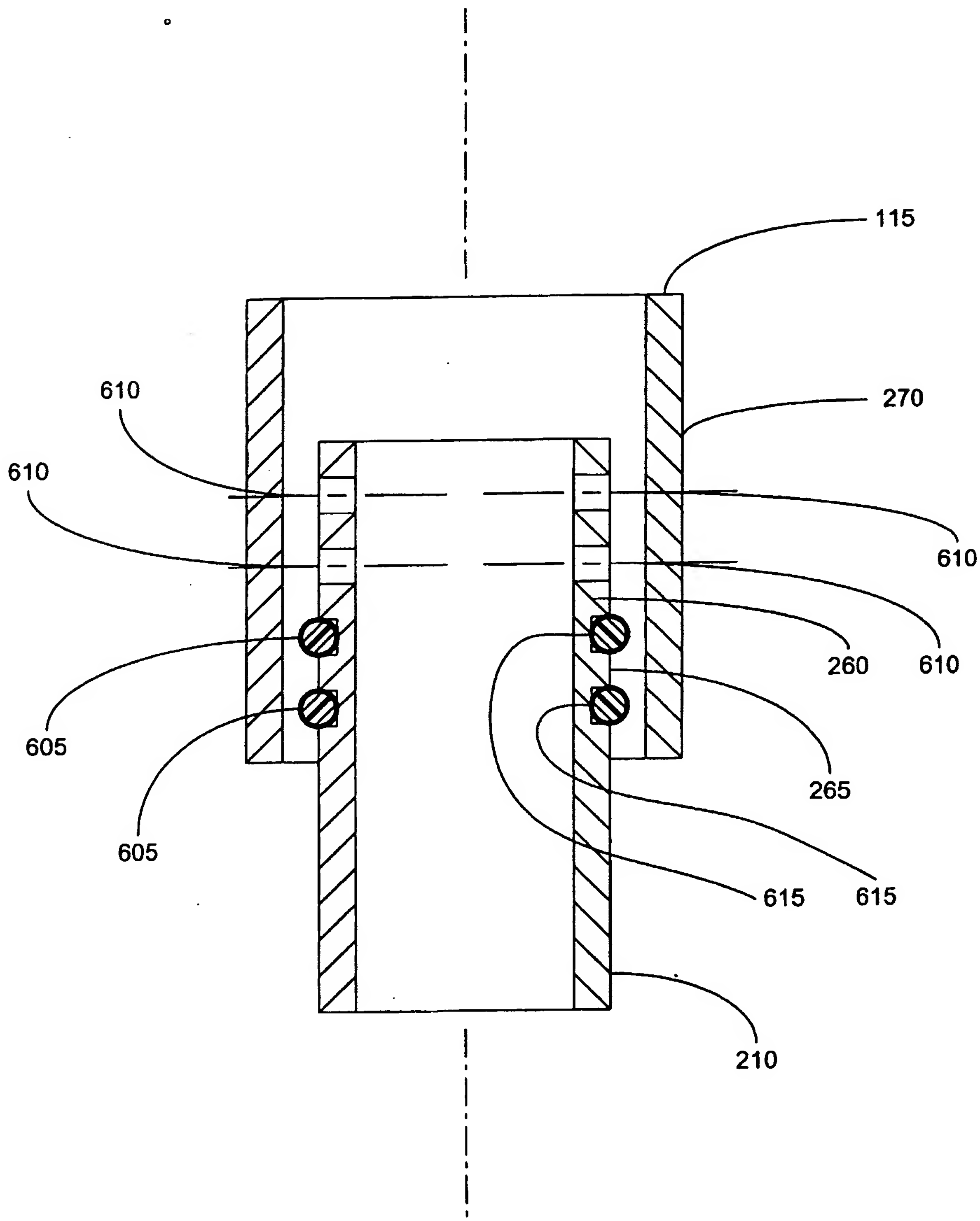

FIGURE 6

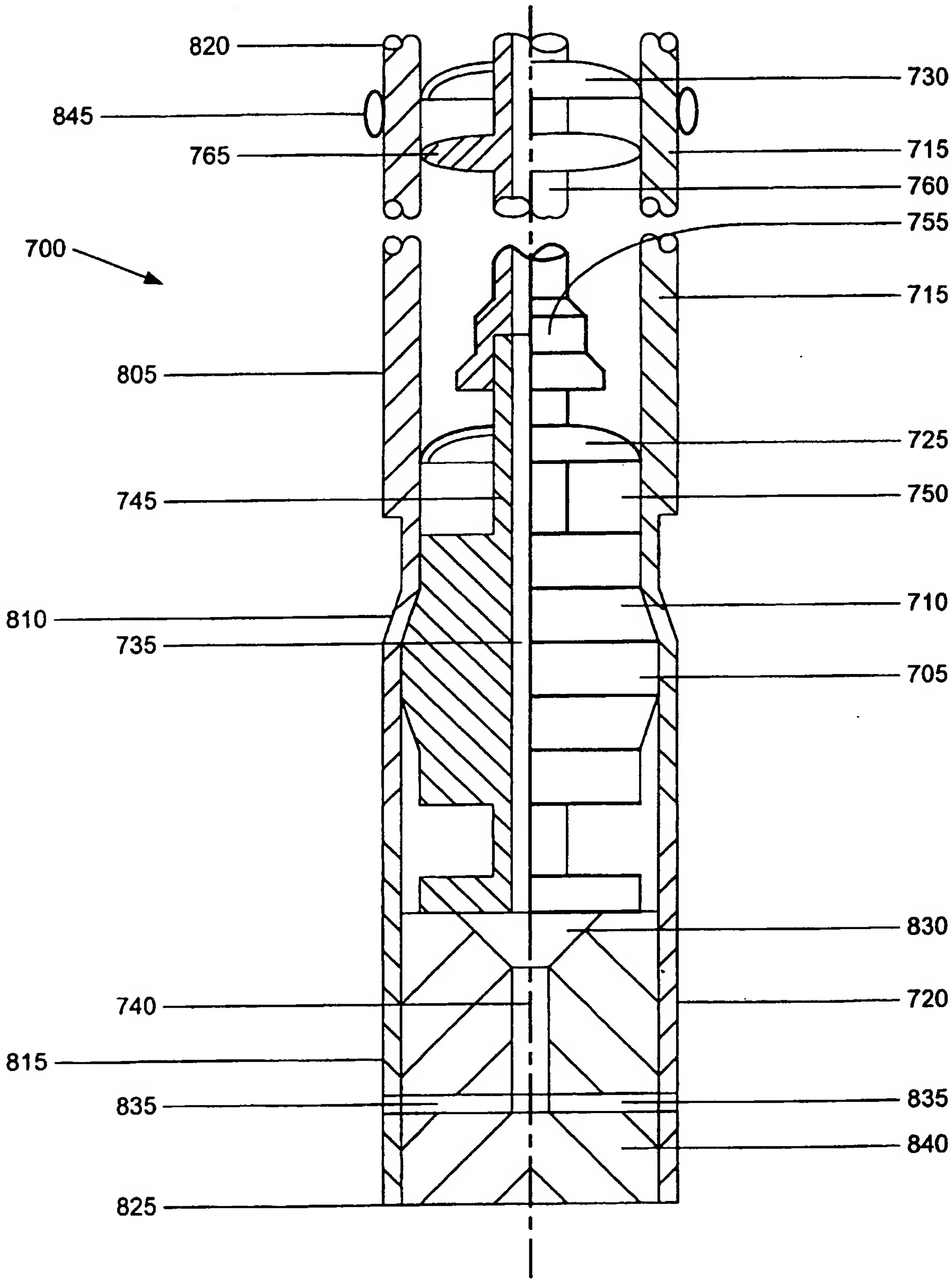
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FIGURE 7

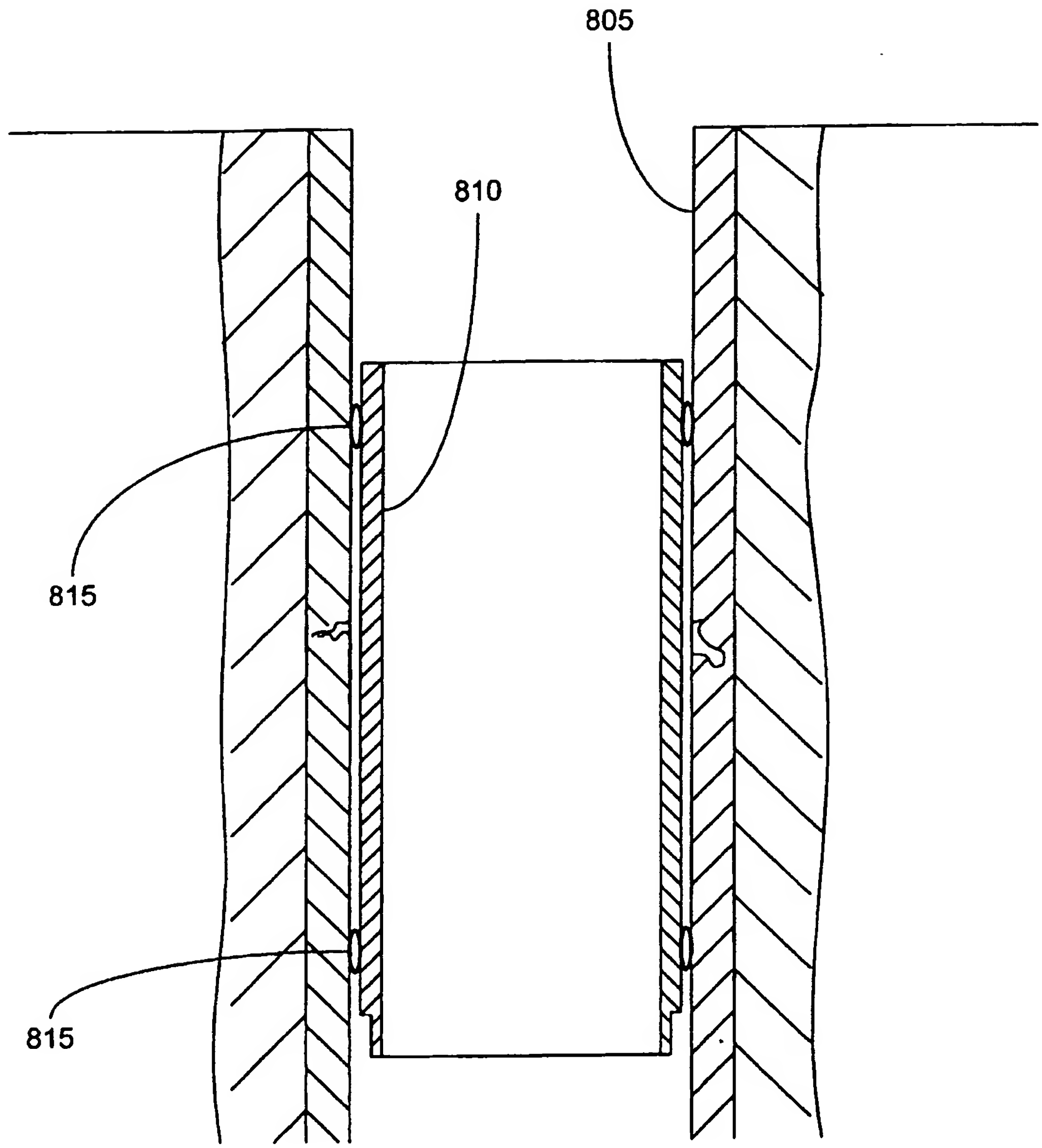

FIGURE 8

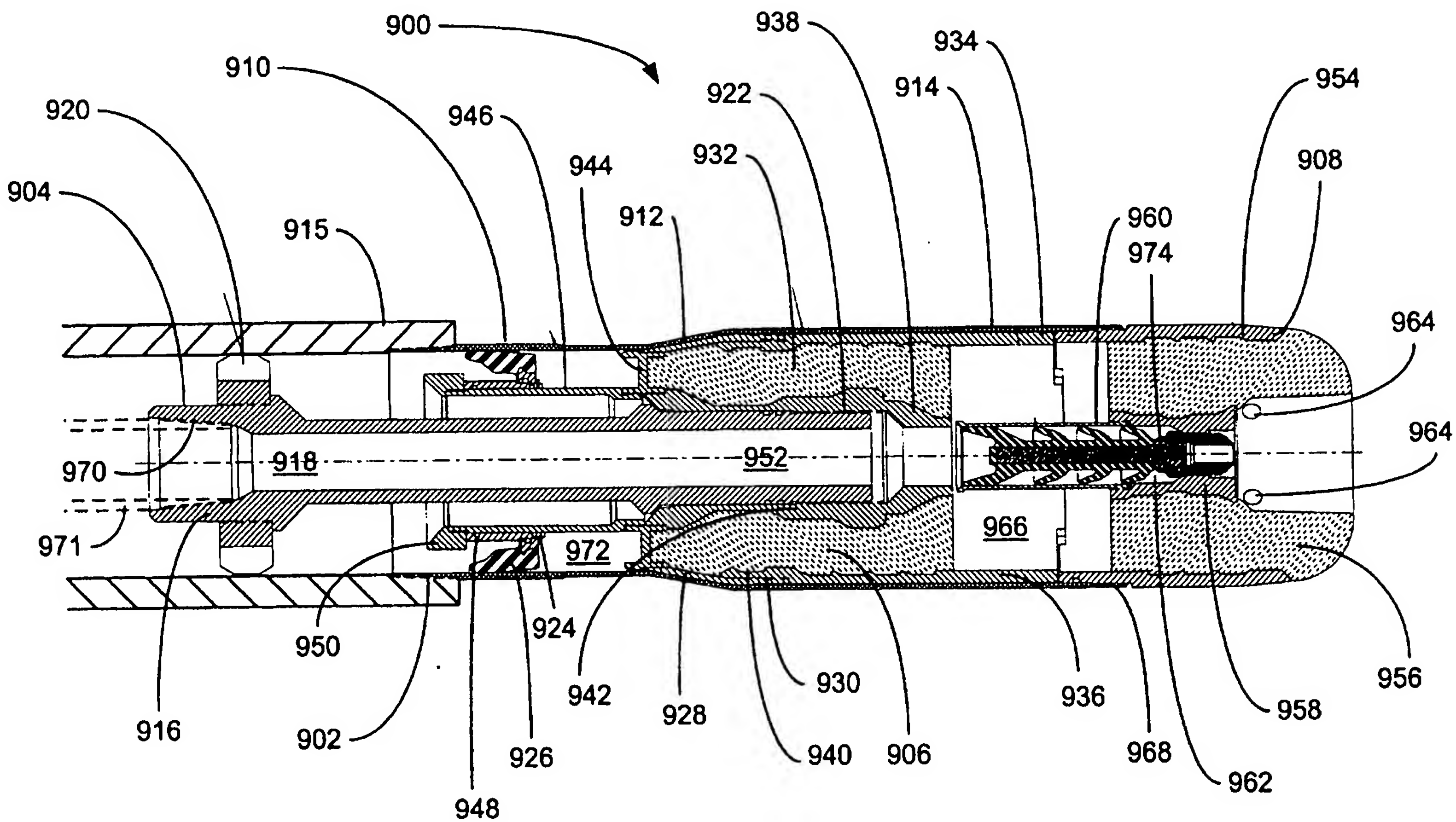

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FIGURE 9

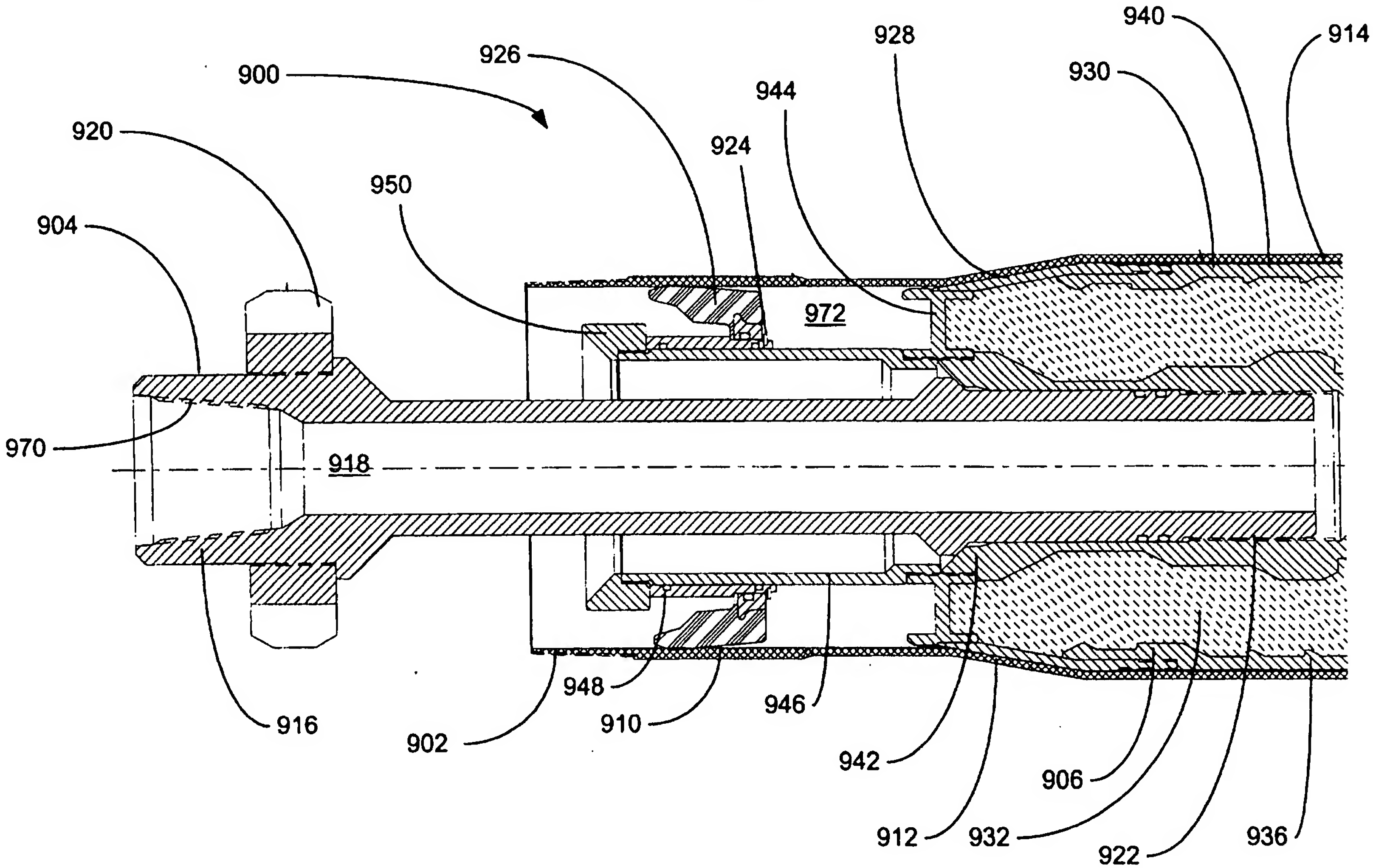
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FIGURE 9a

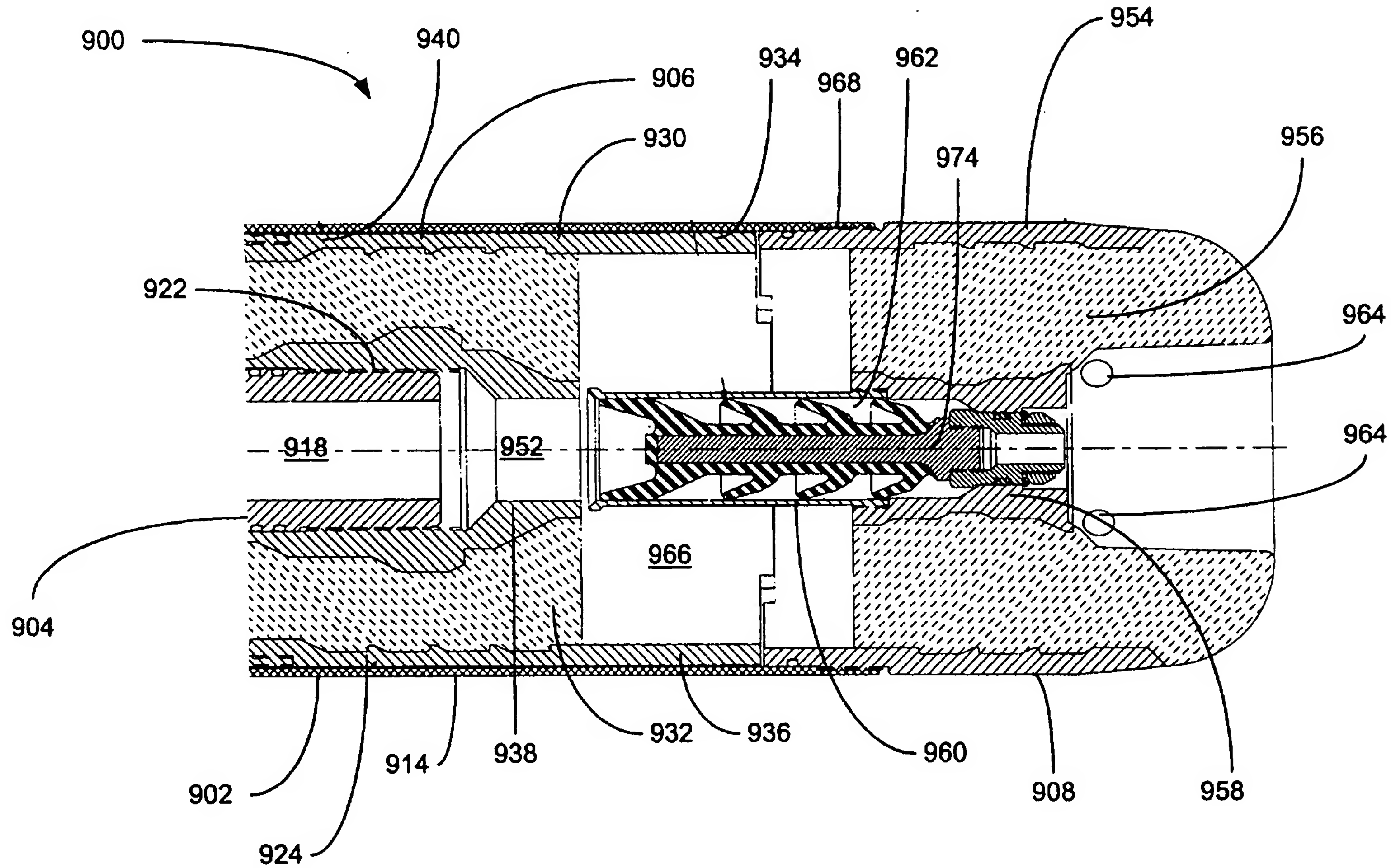
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FIGURE 9b

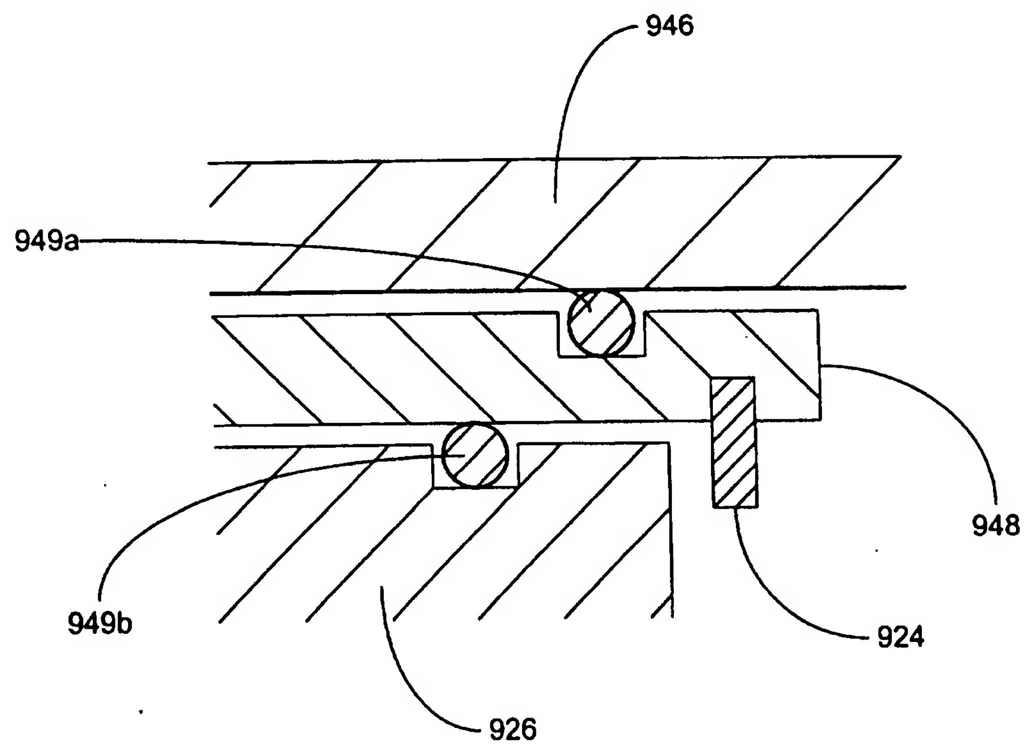

FIGURE 9C

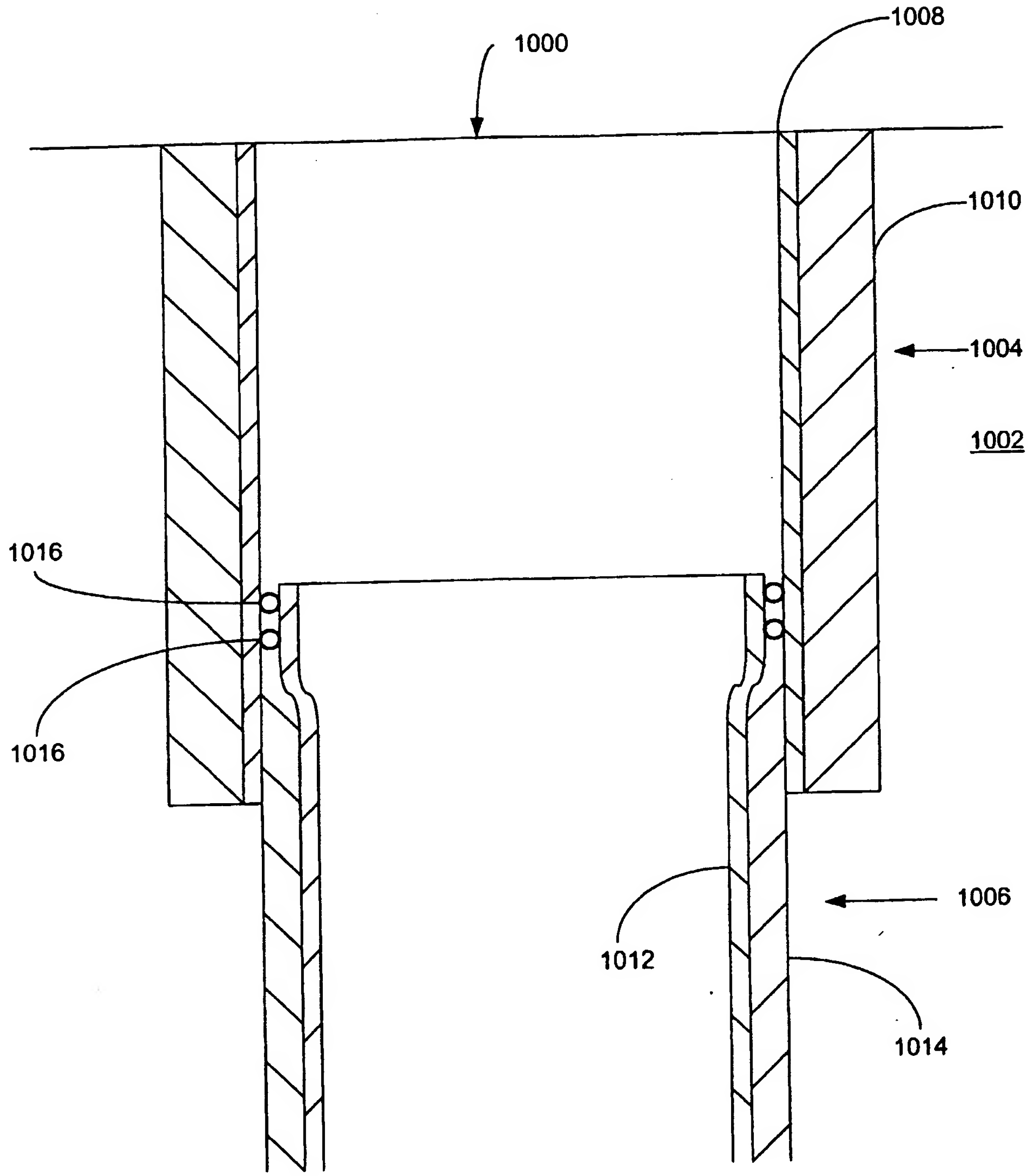

FIGURE 10a

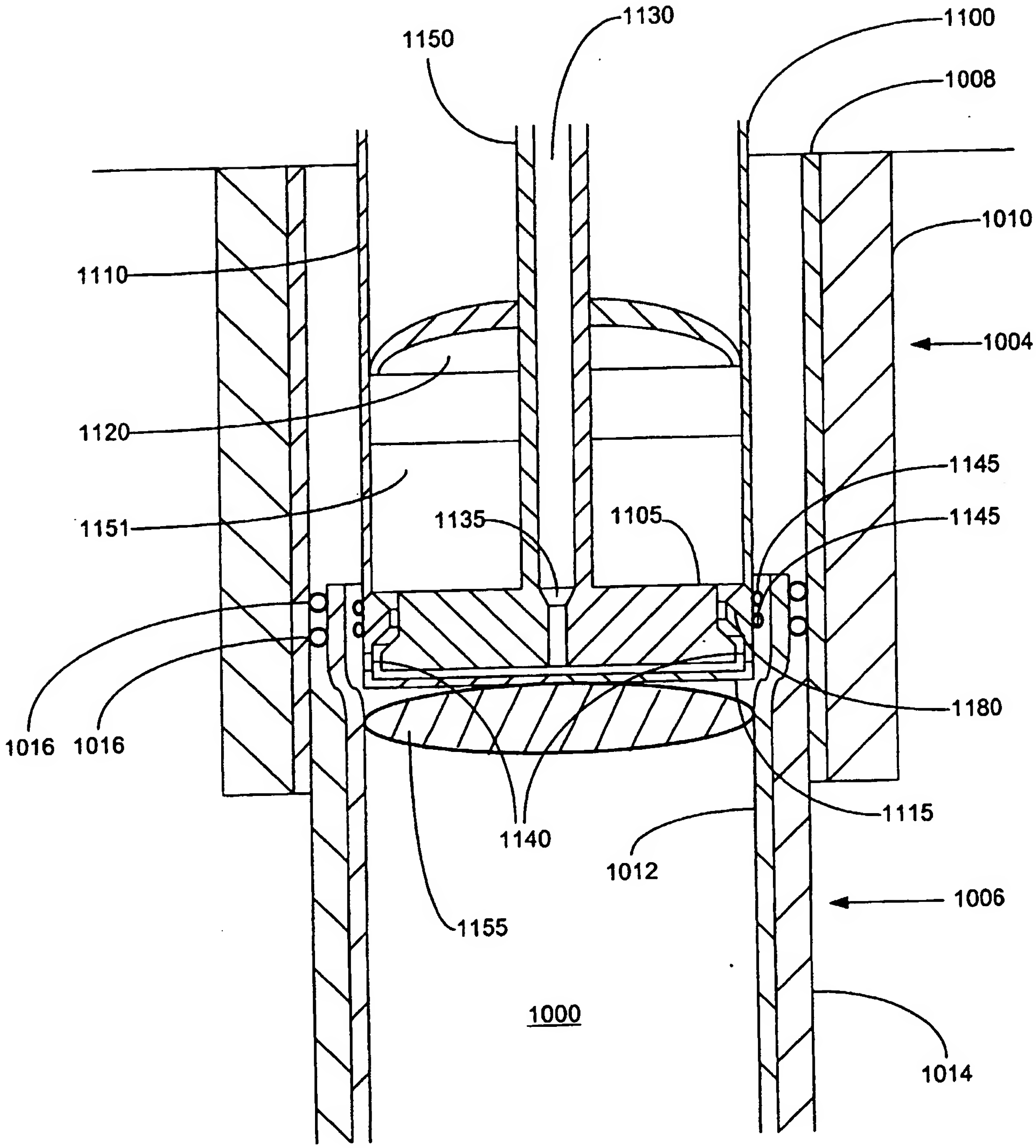
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FIGURE 10b

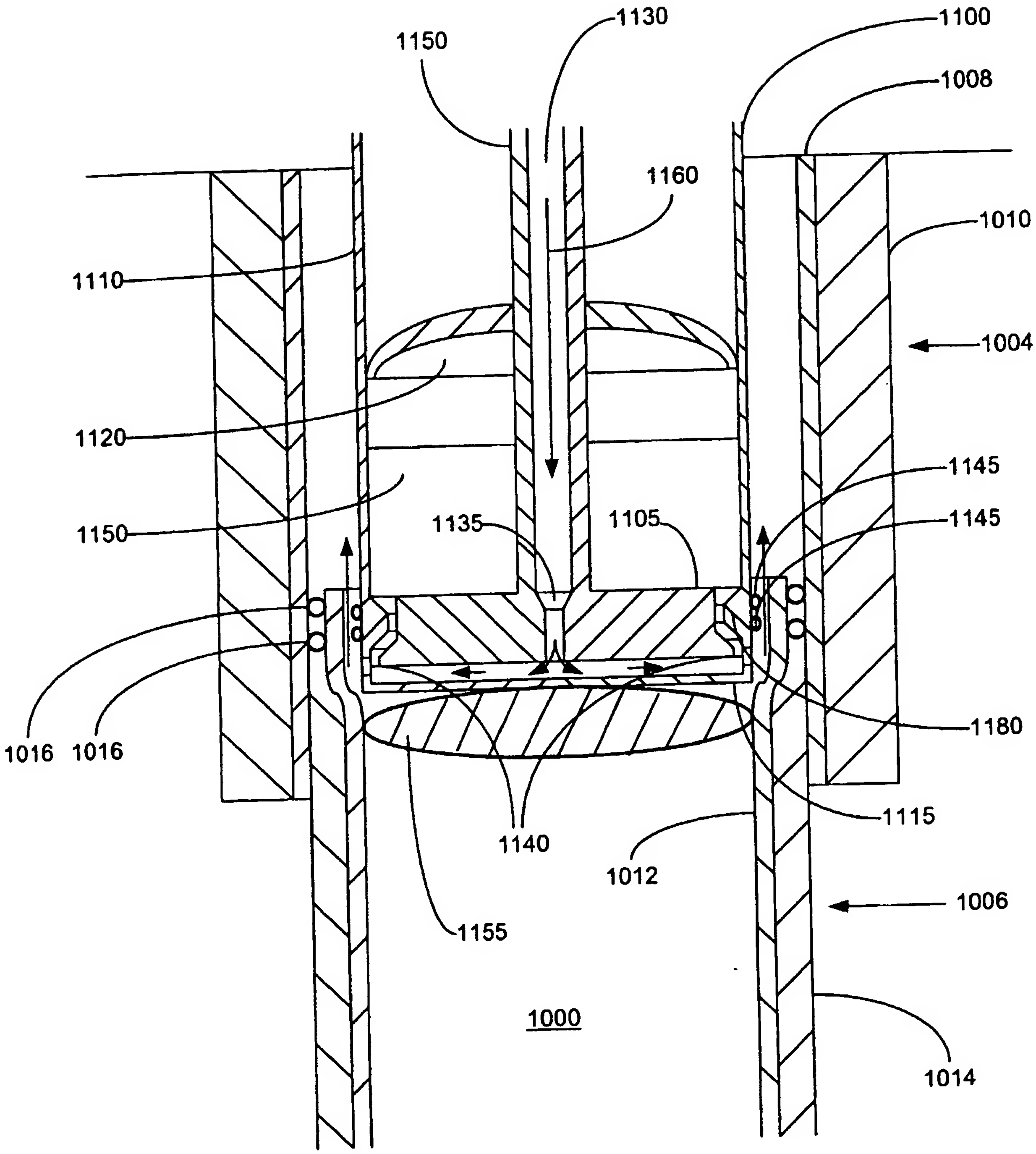
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FIGURE 10c

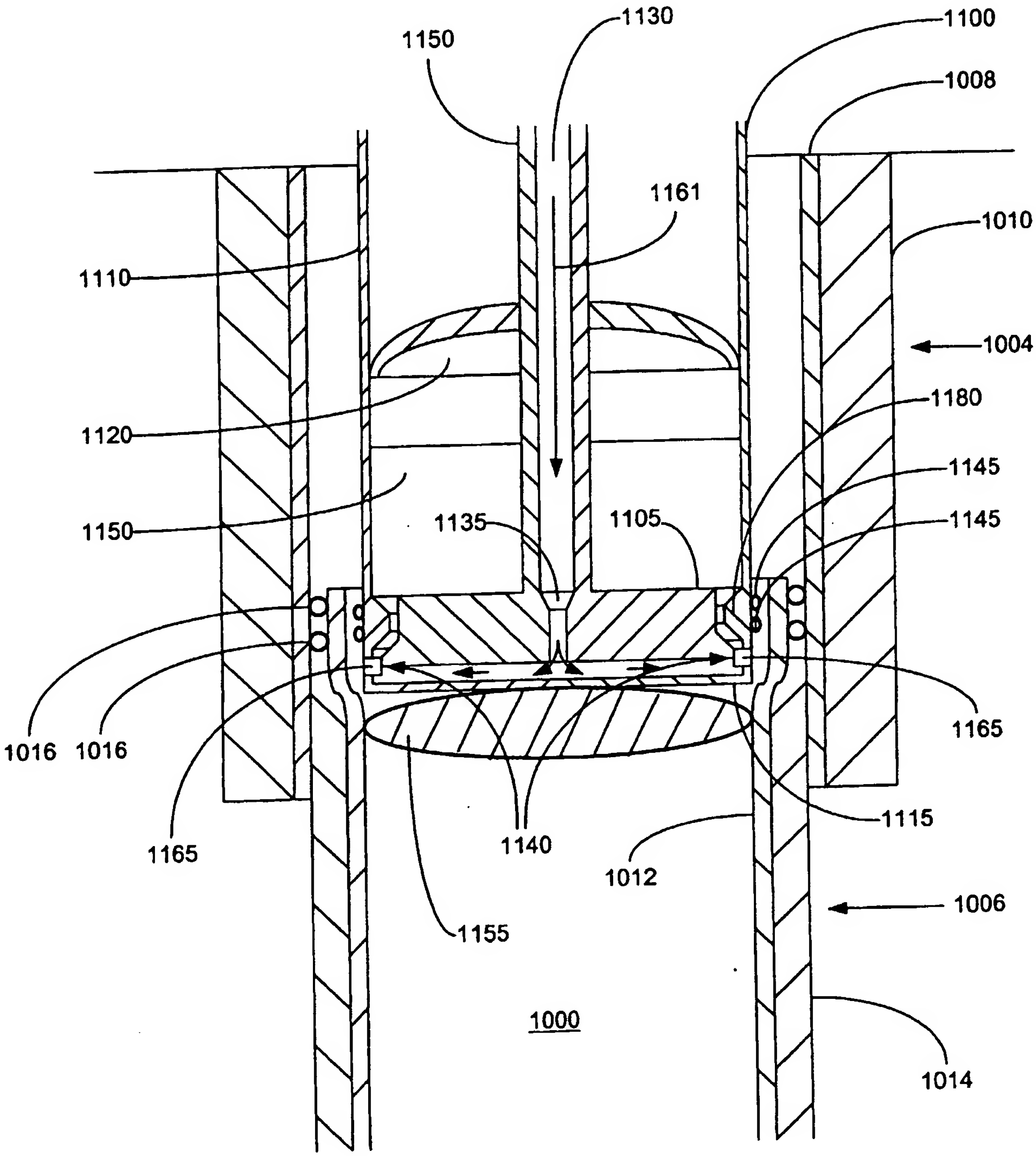
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FIGURE 10d

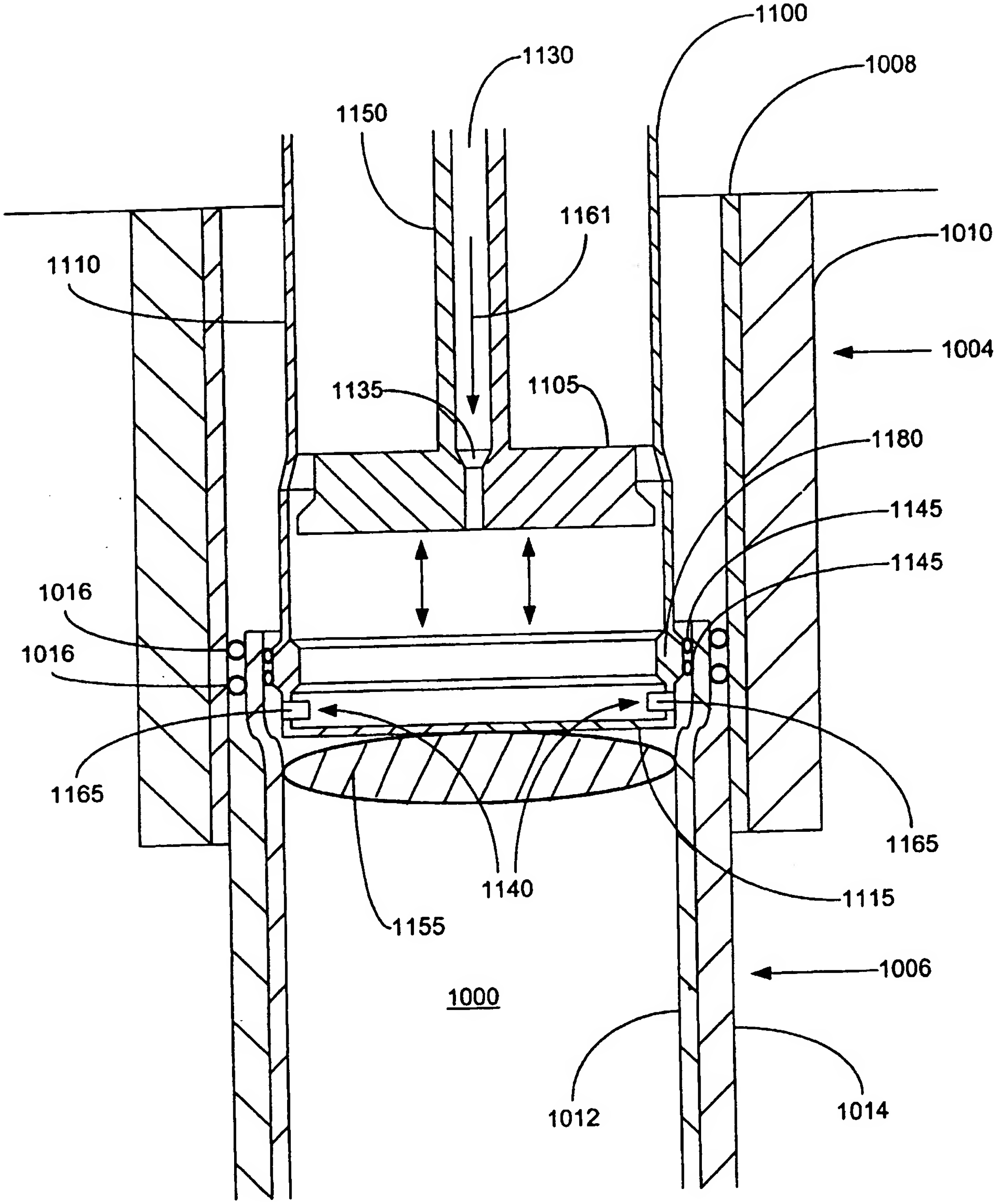
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FIGURE 10e

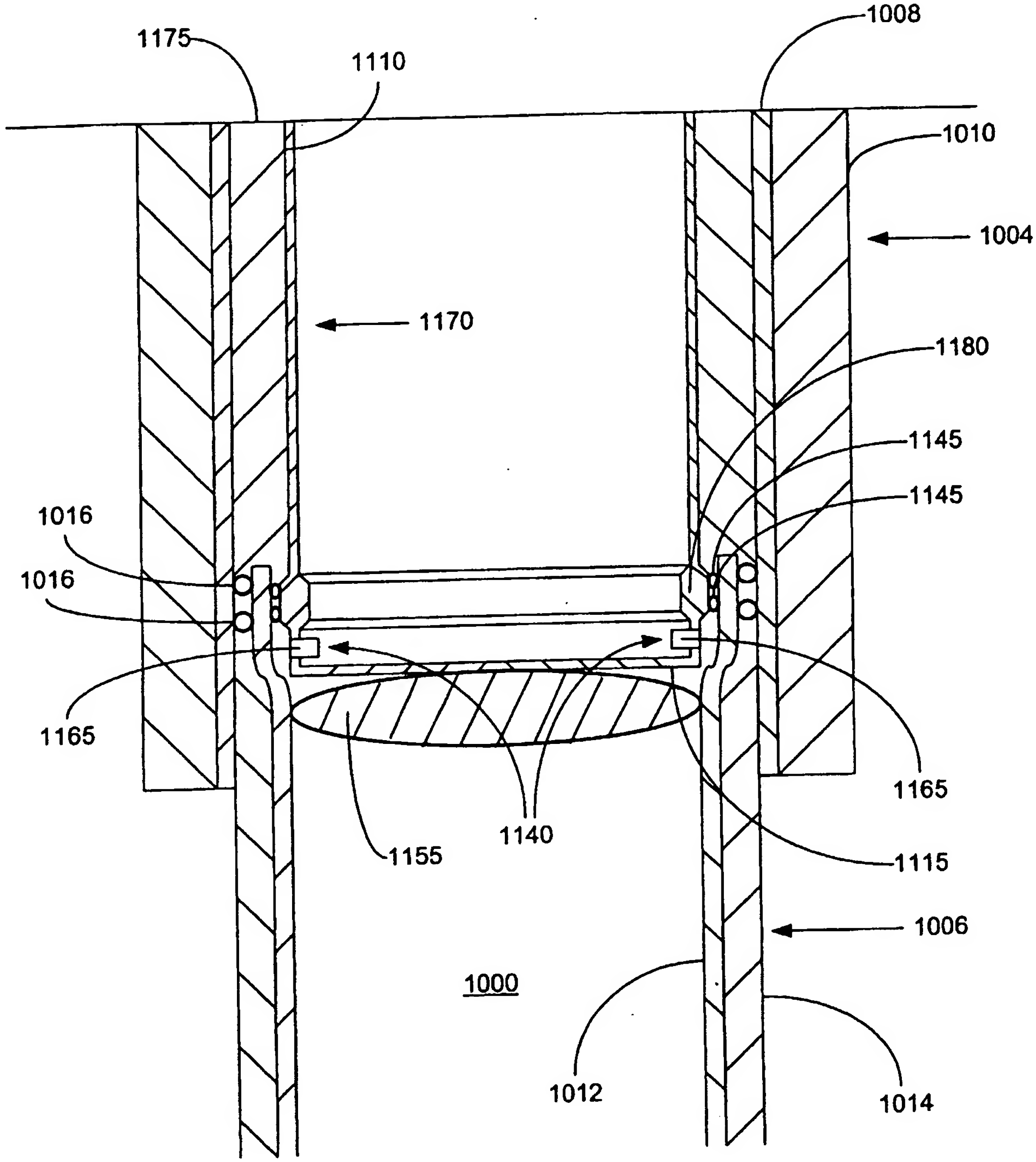
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FIGURE 10f

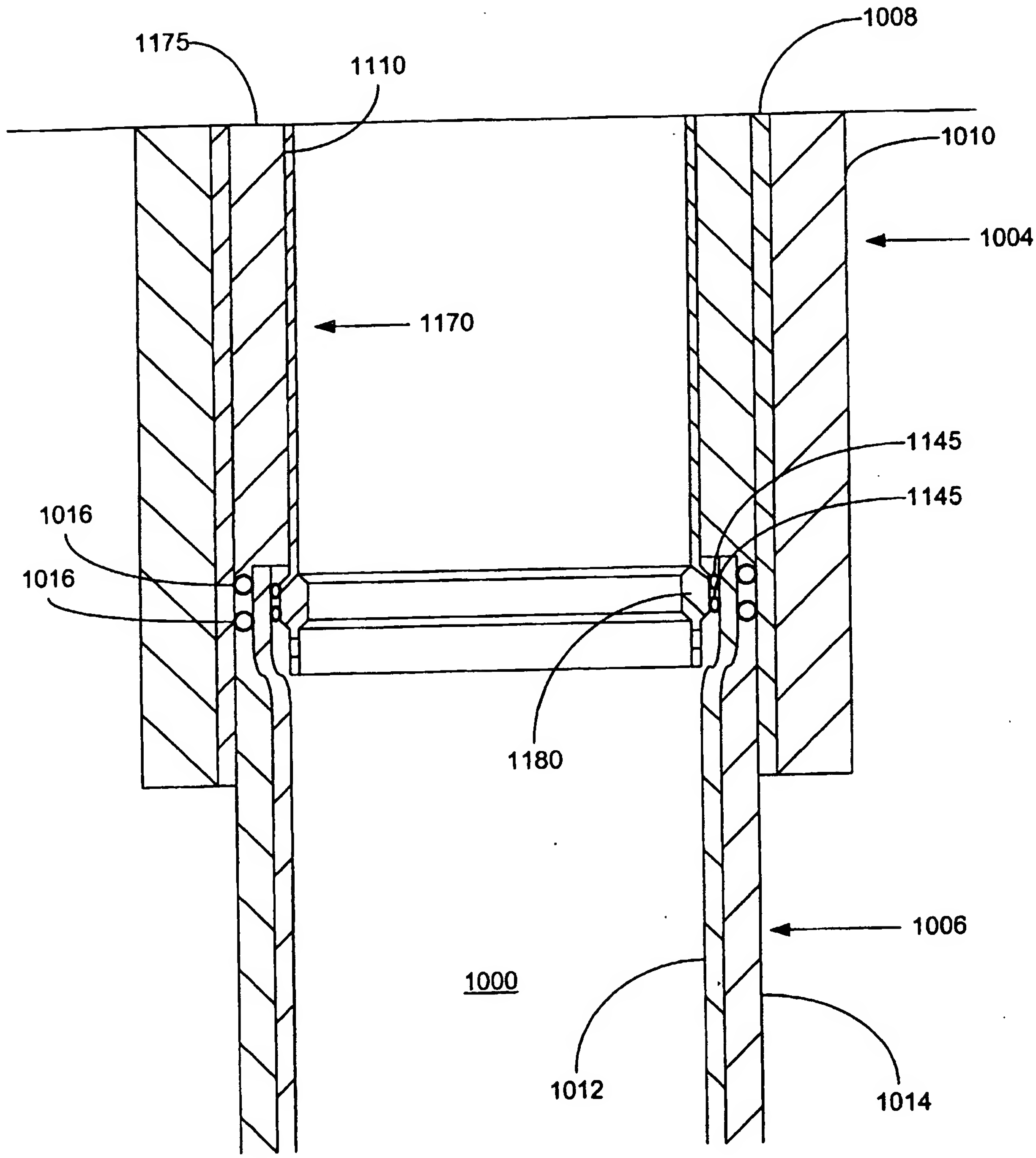
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FIGURE 10g

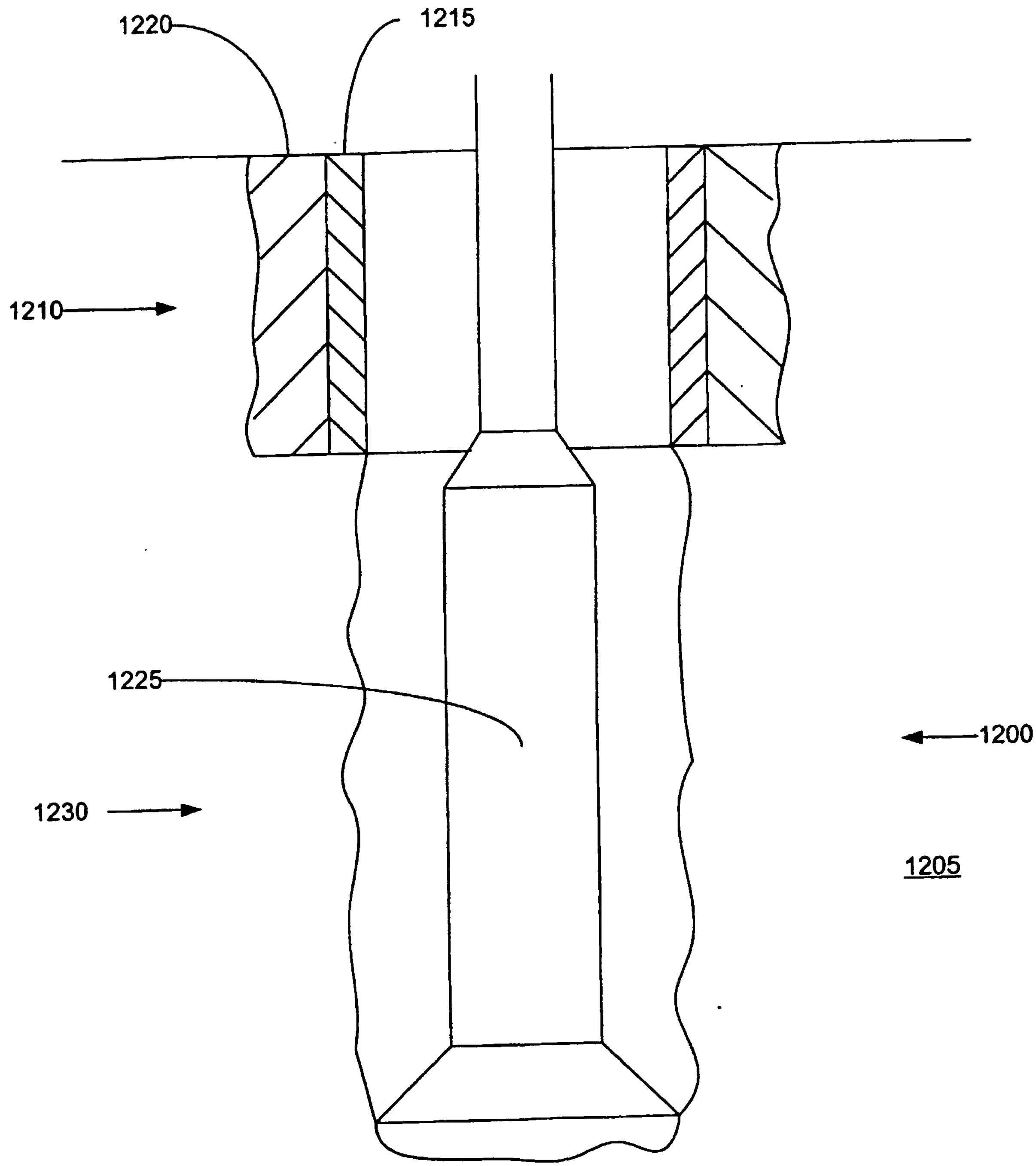

FIGURE 11a

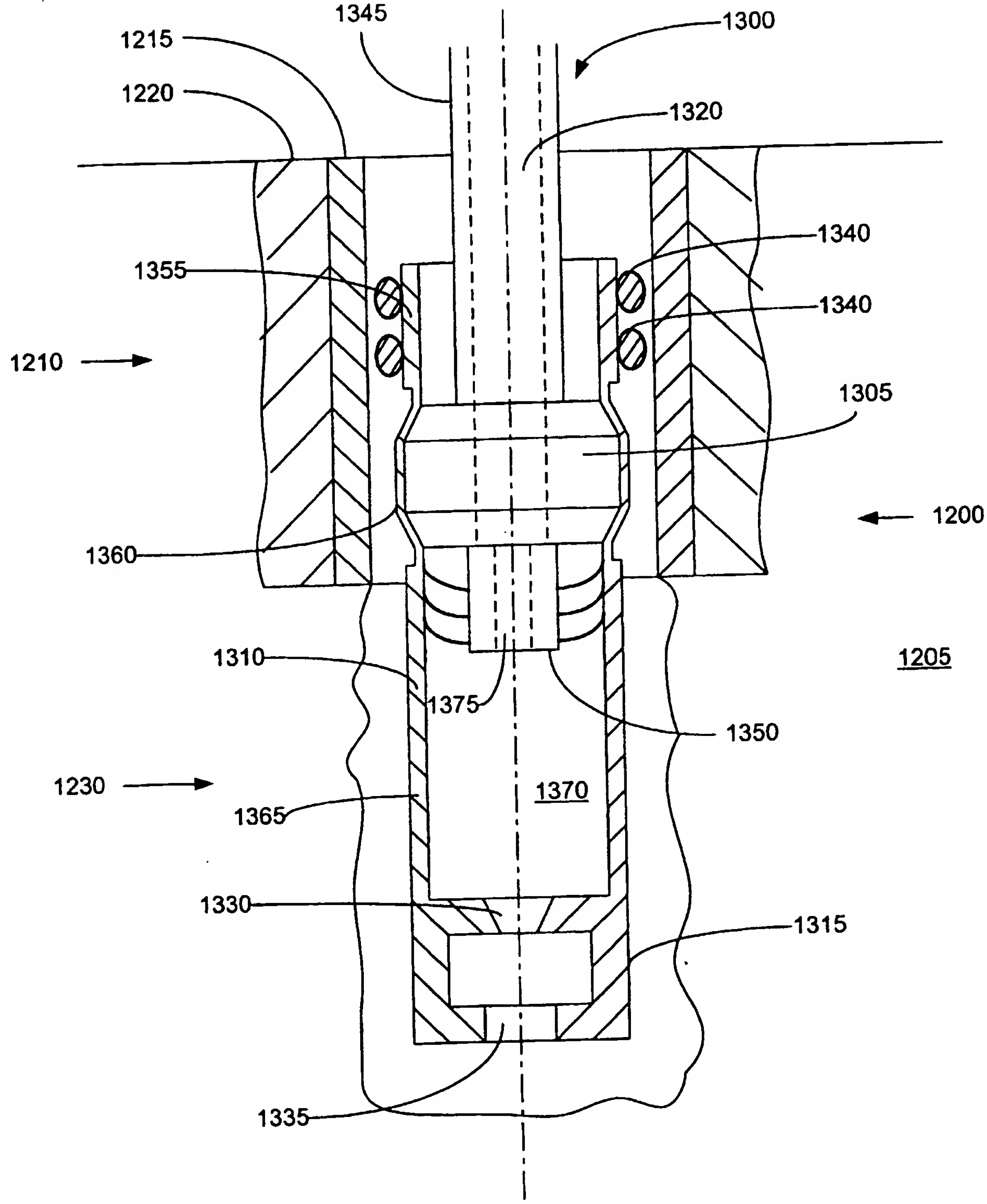
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FIGURE 11b

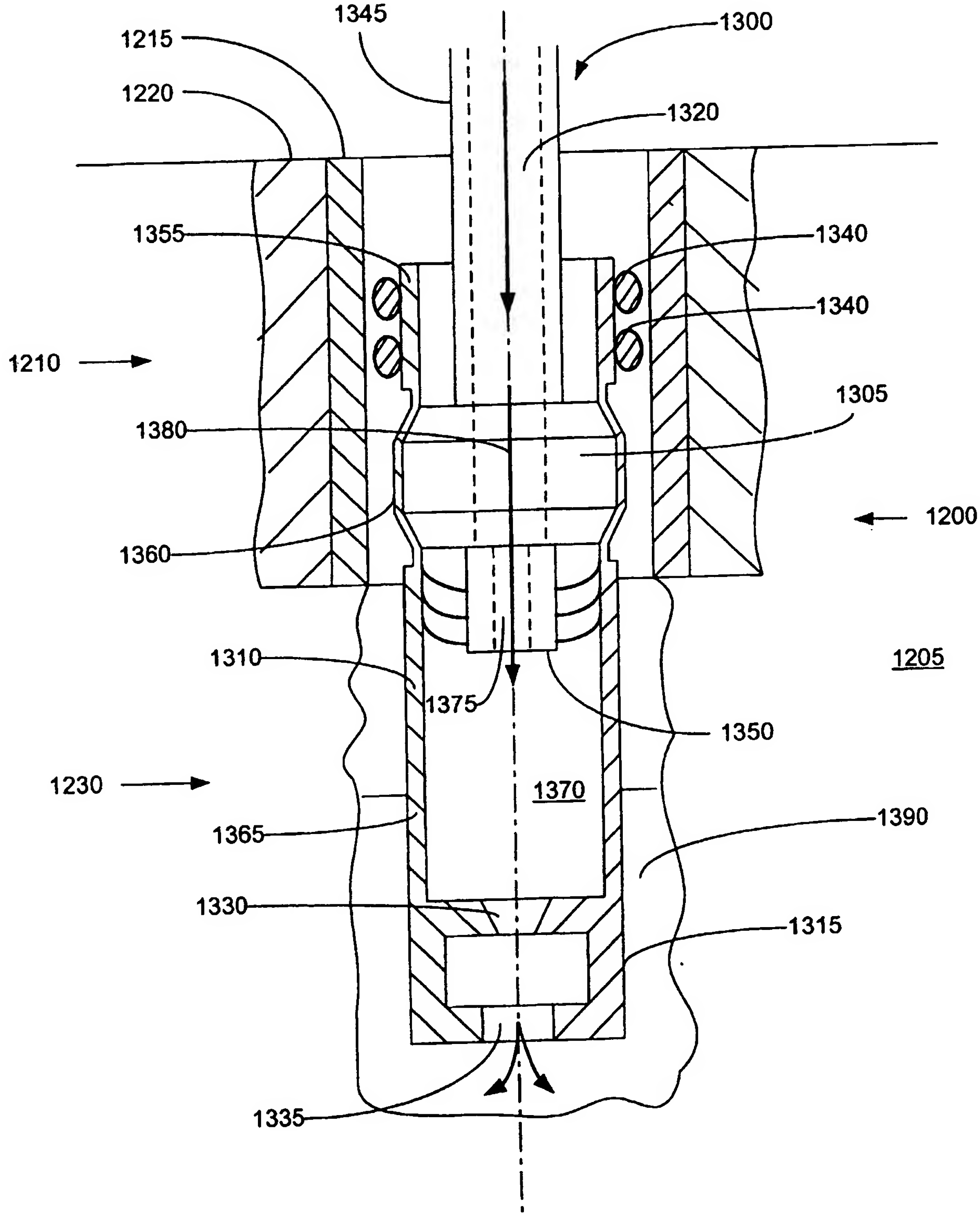
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FIGURE 11c

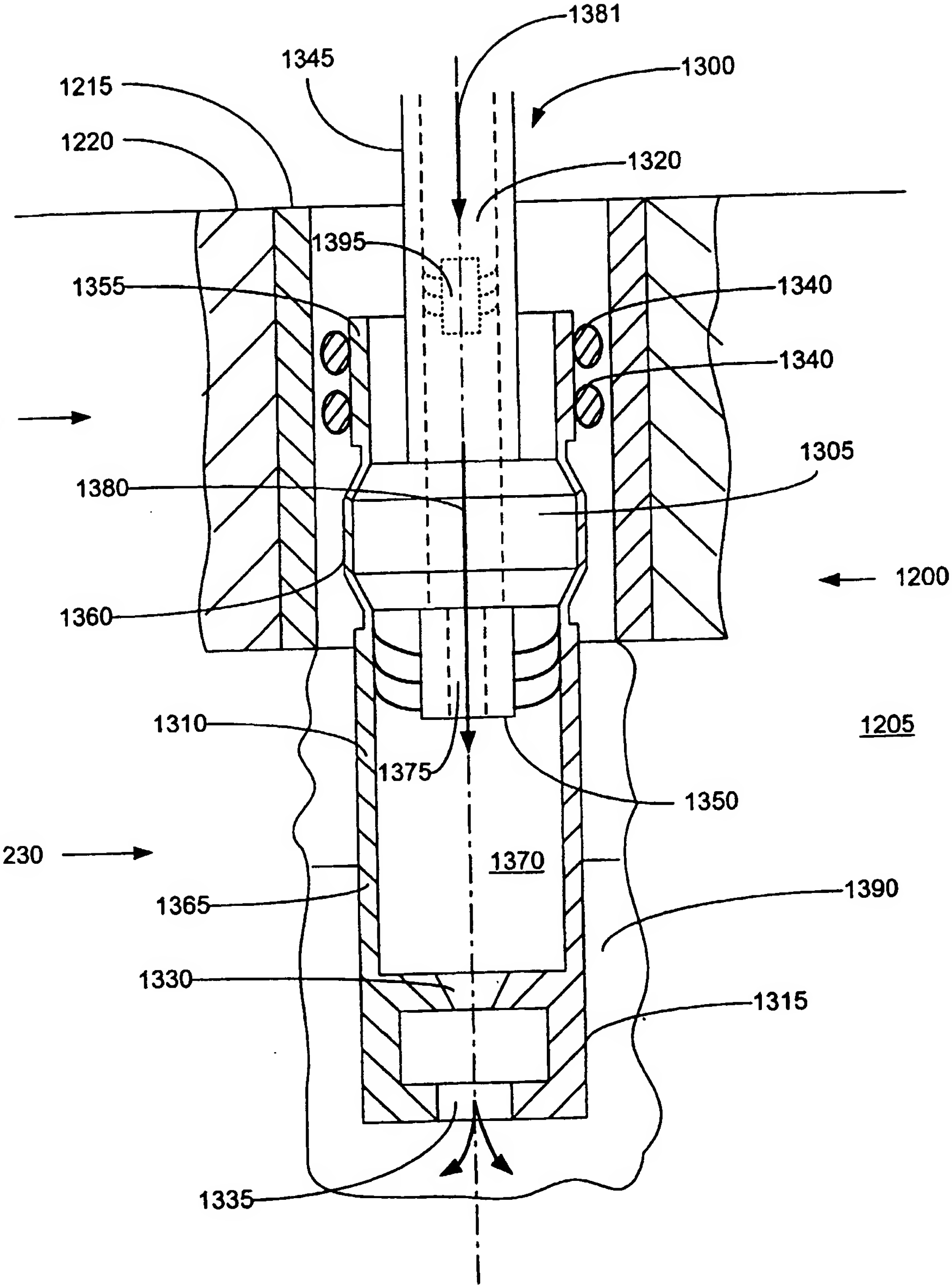
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FIGURE 11d

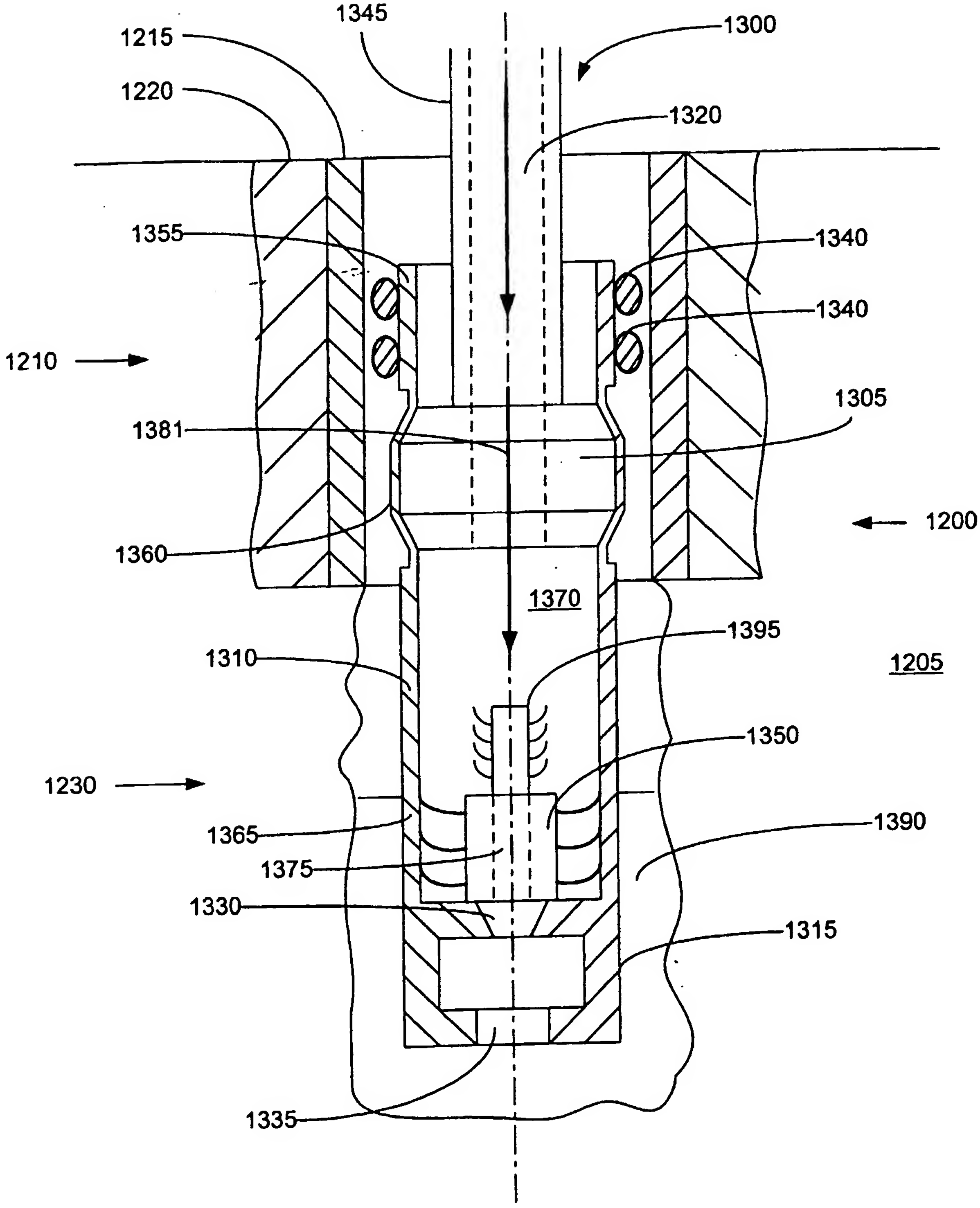
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FIGURE 11e

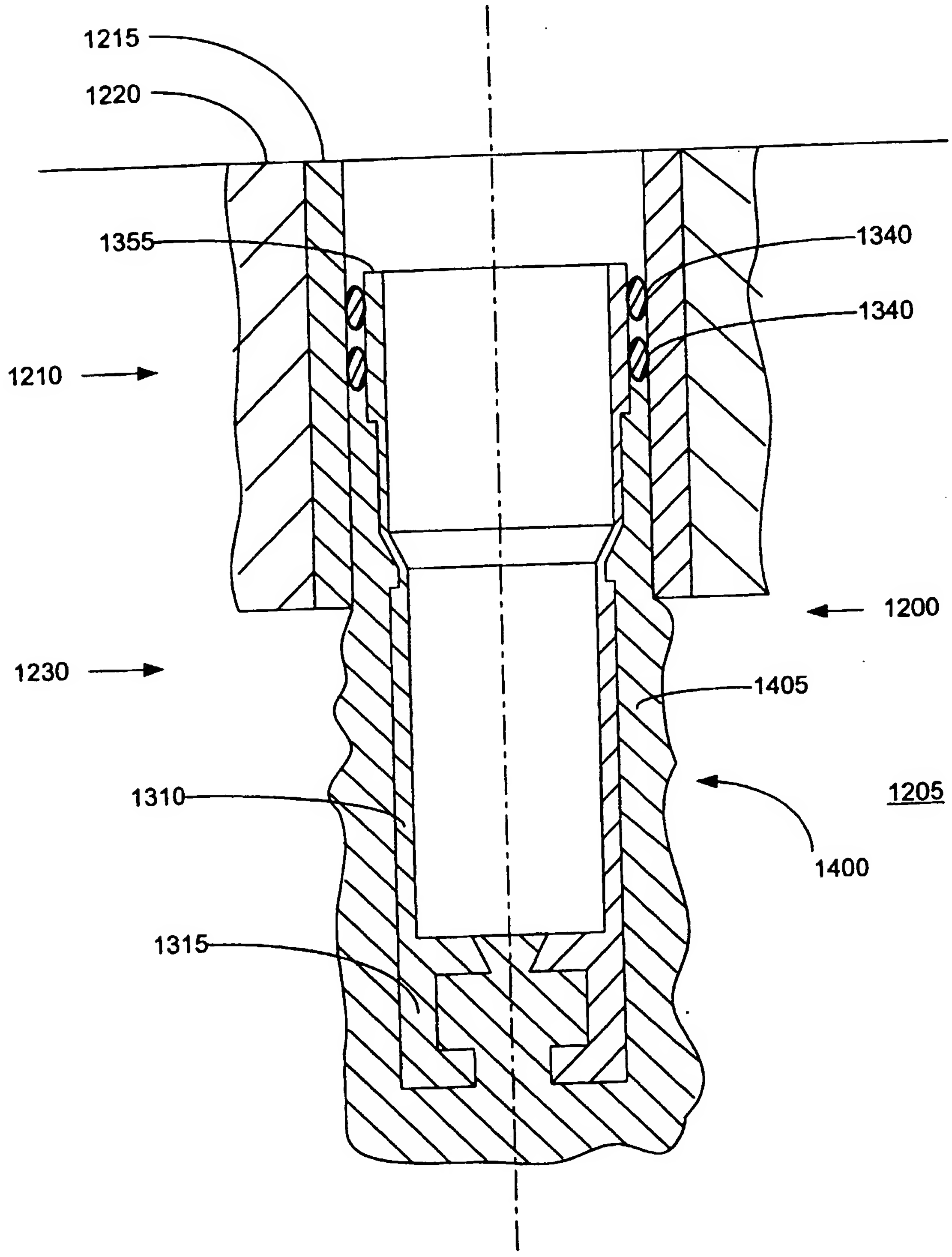

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FIGURE 11f

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sealing member 380 is preferably selected to be less than the outside diameters of the first and second ends, 420 and 430, of the tubular body 405 in order to optimally protect the sealing member 380 during placement of the tubular member 370 within the typical range of wellbore casings 100. The sealing member 380 may be fabricated from any number of conventional commercially available materials such as, for example, thermoset or thermoplastic polymers. The sealing member 380 is fabricated from thermoset polymers in order to optimally seal the interface between the radially expanded intermediate portion 425 of the tubular body 405 and the wellbore casing 100.

During placement of the tubular member 370 within the wellbore casing 100, the protective coatings provided on the exterior surfaces of the first and second ends, 420 and 430, of the tubular body 405 prevent abrasion with the interior surface of the wellbore casing 100. After radial expansion of the tubular body 405, the sealing member 380 seals the interface between the outside surface of the intermediate portions 425 of the tubular body 405 of the tubular member 370 and the inside surface of the wellbore casing 100. During placement of the tubular member 370 within the wellbore casing 100, the sealing member 380 is preferably protected from contact with the interior walls of the wellbore casing 100 by the recessed outer surface profile of the tubular member 370.

The tubular body 405 of the tubular member 370 further includes first and second transition portions, 435 and 440, coupled between the first and second ends, 420 and 430, and the intermediate portion 425 of the tubular body 405. The first and second transition portions, 435 and 440, are inclined at an angle, α, relative to the longitudinal direction ranging from about 0 to 30 degrees in order to optimally facilitate the radial expansion of the tubular member 370. The first and second transition portions, 435 and 440, provide a smooth transition between the first and second ends, 420 and 440, and the intermediate portion 425, of the tubular body 405 of the tubular member 370 in order to minimize stress concentrations.

Referring to FIG. 5, The tubular member 370 is formed by a process 500 that includes the steps of: (1) expanding both ends of the tubular body 405 in step 505;

In step 515, the sealing member 380 is then applied onto the outside diameter of the non-expanded intermediate portion 425 of the tubular body 405. The sealing member 380 may be applied to the outside diameter of the non-expanded intermediate portion 425 of the tubular body 405 using any number of conventional commercially available methods. The sealing member 380 is applied to the outside diameter of the intermediate portion 425 of the tubular body 405 using commercially available chemical and temperature resistant adhesive bonding.

As illustrated in FIG. 6, the interior surface of the tubular body 405 of the tubular member 370 further includes a coating 605 of a lubricant. The coating 605 of lubricant may be applied using any number of conventional methods such as, for example, dipping, spraying, sputter coating or electrostatic deposition. The coating 605 of lubricant is chemically, mechanically, and/or adhesively bonded to the interior surface of the tubular body 405 of the tubular member 370 in order to optimally provide a durable and consistent lubricating effect. The force that bonds the lubricant to the interior surface of the tubular body 405 of the tubular member 370 is greater than the shear force applied during the radial expansion process.

The coating 605 of lubricant is applied to the interior surface of the tubular body 405 of the tubular member 370 by first applying a phenolic primer to the interior surface of the tubular body 405 of the tubular member 370, and then bonding the coating 605 of lubricant to the phenolic primer using an antifriction paste including the coating 605 of lubricant carried within an epoxy resin. The antifriction paste includes, by weight, 40-80% epoxy resin, 15-30% molybdenum disulfide, 10-15% graphite, 5-10% aluminum, 5-10% copper, 8-15% alumisilicate, and 5-10% polyethylenepolyamine. The antifriction paste is provided substantially as disclosed in U.S. Patent No. 4,329,238, the disclosure of which is incorporate herein by reference.

The coating 605 of lubricant may be any number of conventional commercially available lubricants such as, for example, metallic soaps or zinc phosphates. The coating 605 of lubricant includes C-Lube-10, C-Phos-52, C-Phos-58-M, and/or C-Phos-58-R in order to optimally provide a coating of lubricant. The

coating 605 of lubricant provides a sliding coefficient of friction less than about 0.20 in order to optimally reduce the force required to radially expand the tubular member 370 using the expansion cone 375.

The coating 605 includes a first part of a lubricant. The first part of the lubricant forms a first part of a metallic soap. The first part of the lubricant coating includes zinc phosphate. The second part of the lubricant is circulated within a fluidic carrier that is circulated into contact with the coating 605 of the first part of the lubricant during the radial expansion of the tubular member 370. The first and second parts of the lubricant react to form a lubricating layer between the interior surface of the tubular body 405 of the tubular member 370 and the exterior surface of the expansion cone 375 during the radial expansion process. In this manner, a lubricating layer is optimally provided in the exact concentration, exactly when and where it is needed. Furthermore, because the second part of the lubricant is circulated in a carrier fluid, the dynamic interface between the interior surface of the tubular body 405 of the tubular members 370 and the exterior surface of the expansion cone 375 is also preferably provided with hydrodynamic lubrication. The first and second parts of the lubricant react to form a metallic soap. The second part of the lubricant is sodium stearate.

The expansion cone 375 is movably coupled to the second support member 340. The expansion cone 375 is preferably adapted to be axially displaced upon the pressurization of the interior region 385 of the expandable tubular member 370. The expansion cone 375 is further preferably adapted to radially expand the expandable tubular member 370.

As illustrated in FIG. 7, the expansion cone 375 includes a conical outer surface 705 for radially expanding the tubular member 370 having an angle of attack α. As illustrated in FIG. 8, the angle of attack α ranges from about 10 to 40 degrees in order to minimize the required operating pressure of the interior portion 385 during the radial expansion process.

Referring to FIG. 9, an expansion cone 900 for use in the repair apparatus 300 includes a front end 905, a rear end 910, and a radial expansion section 915.

Claims

1. An expansion device for expanding a tubular member, comprising:
a housing including a tapered first end and a second end
one or more grooves formed in the outer surface of the tapered first end; and
one or more axial flow passages fluidicly coupled to the or each groove;
wherein the or each groove comprises a spiral groove.

2. An expansion device for expanding a tubular member, comprising
a housing including a tapered first end and a second end;
one or more grooves formed in the outer surface of the tapered first end; and
one or more axial flow passages fluidicly coupled to the or each groove;
wherein the or each axial flow passage comprises an axial groove.

3. The expansion device of claim 2, wherein there are a plurality of axial grooves which are spaced apart by at least 76.2 mm (3 inches) in the circumferential direction.

4. The expansion device of claim 2, wherein the or each axial groove extends from the tapered first end of the body to the or each groove.

5. The expansion device of claim 2, wherein the or each axial groove extends from the second end of the body to the or each groove.

6. The expansion device of claim 2, wherein the or each axial groove extends from the tapered first end of the body to the second end of the body.

7. An expansion device for expanding a tubular member, comprising:
a housing including a tapered first end and a second end;
one or more grooves formed in the outer surface of the tapered first end;
one or more axial flow passages fluidicly coupled to the or each groove;

wherein the or each axial flow passage is positioned within the housing of the expansion device;

wherein the or each axial flow passage extends from the tapered first end of the body to the or each groove.

8. The expansion device of claims 1, 2 or 7, wherein the or each flow passage extends from the tapered first end of the body to the second end of the body.

9. The expansion device of claims 1, 2 or 7, wherein the or each flow passage extends from the second end of the body to the or each groove.

10. The expansion device of claims 1, 2 or 7, wherein at least one of the or each axial flow passage includes an insert having a restricted flow passage.

11. The expansion device of claims 1, 2 or 7, wherein at least one of the or each axial flow passage includes a filter.

12. The expansion device of claims 1, 2 or 7, wherein the cross sectional area of the or each groove is greater than the cross sectional area of the or each axial flow passage.

13. The expansion device of claims 1, 2 or 7, wherein the cross-sectional area of the or each groove ranges from 129×10^{-3} mm^2 to 32.26 mm^2 (2×10^{-4} in^2 to 5×10^{-2} in^2).

14. The expansion device of claims 1, 2 or 7, wherein the cross-sectional area of the or each axial flow passage ranges from 129×10^{-3} mm^2 to 32.26 mm^2 (2×10^{-4} in^2 to 5×10^{-2} in^2).

15. The expansion device of claims 1, 2 or 7, wherein the or each groove is concentrated in a trailing edge portion of the tapered first end.

16. The expansion device of claims 1, 2 or 7, wherein the angle of inclination of the or each axial flow passage relative to the longitudinal axis of the expansion device is greater than the angle of attack of the first tapered end.

17. The expansion device of claims 1, 2 or 7, wherein the or each groove includes:

a flow channel having a first radius of curvature;

a first shoulder positioned on one side of the flow channel having a second radius of curvature; and

a second shoulder positioned on the other side of the flow channel having a third radius of curvature.

18. The expansion device of claim 17, wherein the first, second and third radii of curvature are substantially equal.

19. The expansion device of claims 1, 2 or 7, wherein the or each axial flow passage includes:

a flow channel having a first radius of curvature;

a first shoulder positioned on one side of the flow channel having a second radius of curvature; and

a second shoulder positioned on the other side of the flow channel having a third radius of curvature.

20. The expansion device of claim 19, wherein the first, second and third radii of curvature are substantially equal.

21. The expansion device of claim 19, wherein the second radius of curvature is greater than the third radius of curvature.

22. The expansion device of any one of claims 1 to 21, the expansion device coupled to a tubular support member defining a first longitudinal passage extending therethrough.

23. The expansion device of claims 1, 2 or 7, the tubular member comprising an expandable wellbore casing movably coupled to the tapered first end of the expansion device.

24. A method of lubricating the interface between a tubular member and an expansion device having a first tapered end and a second end during the radial expansion of the tubular member by the expansion device, wherein the interface between the tubular member and the first tapered end of the expansion device includes one or more grooves formed in an outer surface, one or more axial flow passages fluidicly coupled to the grooves, a leading edge portion and a trailing edge portion, comprising:

injecting a lubricating fluid into the trailing edge portion;

wherein the lubricating fluid comprises drilling mud.

25. The method of claim 24, further comprising:

positioning the expansion device at least partially within the tubular member; and

pressurizing a region within the tubular member below the second end of the expansion device.

26. The method of claim 24, wherein the lubricating fluid has a viscosity ranging from 1 to 10,000 centipoise.

27. The method of claim 24, wherein the injecting includes:

injecting lubricating fluid into the first tapered end of the expansion device.

28. The method of claim 27, wherein the injecting includes:

injecting lubricating fluid into the area around the axial midpoint of the first tapered end of the expansion device.

29. The method of claim 24, wherein the injecting includes:

injecting lubricating fluid into the second end of the expansion device.

30. The method of claim 24, wherein the injecting includes:

injecting lubricating fluid into the tapered first end and the second end of the expansion device.

31. The method of claim 24, wherein the injecting includes:

injecting lubricating fluid into the interior of the expansion device.

32. The method of claim 24, wherein the injecting includes:

injecting lubricating fluid through the outer surface of the expansion device.

33. The method of claim 24, wherein the injecting includes:

injecting the lubricating fluid into a plurality of discrete locations along the trailing edge portion.